

PETROGRAPHIC CHARACTERIZATION AND RANK EVALUATION OF COAL SEAMS BELONGING TO KORBA BASIN, CHHATTISGARH, INDIA

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ABSTRACT

Korba coal basin is one of the largest producers of power coal in Central India and coal produced from it finds its applicability in various industries also. The authors have selected 13 coal samples from Lower Barakar and Upper Barakar Formation of Korba coal basin and have investigated petrographic characteristics and shaping of coal rank. The moisture (W^a), volatile matter (V^{daf}) and ash content (A^d) in coal samples vary from 6.22 – 12.40, 31.62 – 45.65 and 9.87 – 35.16 (wt %) respectively. Here, the vitrinite (Vt^{mmf}) and inertinite (I^{mmf}) maceral group show wide variation in their volume contents. The fuel ratio (FR) exhibit a range of 1.19 – 2.16 whereas mean vitrinite reflectance (R^o m %) varies from 0.41 – 0.50%. The petrographic study indicates an increase in vitrinite content and decrease in inertinite content from older (Lower Barakar) to younger (Upper Barakar) seam. This may indicate probable evolution of woody plants and accumulation in forest swamps associated with increase in water level. The coal facies of Korba coal basin varies from telmatic – limno-telmatic – limnic. Technological properties and elemental composition indicate that the rank of the coal varies from sub-bituminous to bituminous. The coal of Korba coal basin have large amount of carbominerites and rocks which may be separated during beneficiation.

KEYWORDS: Carbominerite, Coal Facies, Coal Petrography, Rank

INTRODUCTION

Coal is likely to remain a primary energy resource for decades. Coal based power plants are increasing in India. The coal quality has impact on efficiency of combustion in a power plant. Korba coal basin has emerged as one of the largest coal producing area in Central India having coal reserve of 11,755.66 million tonnes (CMPDI, 2013). The coals from this basin are used mainly for power generation and it is also utilised in cement, fertilizer, brick, sponge iron and other industries. The Korba coal basin is named after Korba town in Bilaspur district of Chhattisgarh, India. The Korba coal basin has an area of 530 sq.km elongated in an East-West direction having 64 km length and width of 4.8 to 16 km approximately. The authors have investigated petrographic characteristics and shaping of coal rank. They have also studied coal facies with the help of microlithotype.

GEOLOGICAL SETTING

The Korba coal basin has a gently undulating terrain with elevation varying from 275 - 335m (hills rise sharply to an elevation of 900m towards East as well as West). The Hasdeo river flowing in southern direction divides the coal basin in two unequal parts (Figure 1). The southern boundary of coal basin is faulted due to which Upper Barakar comes in contact with the basement directly. The northern boundary of the basin is unfaulted and sedimentary rocks lie unconformably over the basement. In the eastern part, Barakar Formation is overlain by Kamthi Formation probably with a disconformity separating them. Kamthi Formation lies in the eastern part of the basin which is not shown in Figure 1. The

coal seams in the Korba coal basin strikes mainly East-West with variation in eastern part swinging from WNW-ESE through NW-SE to N-S. In the north-western part strike of the coal seams indicate a synform with centripetal dips. Coal seams of Korba basin dips from 2° to 8° (CIL, 1993). Korba coal basin has faults aligned in East-West direction. Faults having trends NE-SW and NW-SE are also present. The presence of strike fault has resulted in repetition of coal seams at number of places. The coal seams are found in Lower and Upper member of Barakar Formation which is separated by a barren zone of Middle Barakar. The Lower Barakar Formation exhibit presence of 3 to 4 thin noncaking coal seams. The Upper Barakar Formation contains 21 thick interbanded non-caking coal seams. The Jatraj/Kusmunda group of seams of Upper Barakar are significant. The stratigraphic succession of Korba coal basin is shown in Table 1. Precambrian rocks composed of granites, schists, amphibolites and quartzites crop out along the northern and southern boundaries of the basin.

Talchir Formation: Talchir sediments are found in the vicinity of northern periphery of Korba coal basin. Occurrence of Talchir sediments are also noted in western and northeastern part of the basin (Figure 1). The Talchir Formation is mainly composed of green shale, clay, siltstone and sandstone.

Barakar Formation: Lower Barakar Formation is exposed in northern part of the basin. It comprises of pebbly sandstone with grey shale, carbonaceous shale and thin interbanded impersistent coal seams. The Middle and Upper Barakar Formations are found in southern half of the basin which is composed of grey sandstone, grey shale, carbonaceous shale and thick workable coal seams of power grade.

Kamthi Formation: Kamthi Formation consists of pebbly ferruginous sandstone with torrential bedding. The Kamthi sandstone is found on eastern part of the basin.

MATERIALS AND METHODS

Authors have selected 13 coal samples of various coal seams belonging to Lower Barakar and Upper Barakar Formation (Table 2). Three samples A1, B2, C3 belong to Lower Barakar Formation. Samples D4 and E5 (Jatraj group of coal seam XVII) belong to Lower Kusmunda bottom of Upper Barakar Formation. Samples F6, G7, H8 and I9, J10, K11, L12, M13 were taken from Lower Kusmunda seam and Upper Kusmunda seam respectively from different locations. The samples were macroscopically investigated. Various lithotypes were distinguished and lithotype composition was determined. The coal samples were crushed to less than 1mm size and representative splits were taken for preparation of pellets to carry out petrographic and reflectance analyses. These samples were studied under reflected light in Leitz MPV2 microscope with immersion lens and fluorescence attachment following standard procedures (ICCP, 1971, 1998, 2001). The remaining part of the sample was crushed to less than 72 mesh size for determination of technological properties and ultimate composition of coal samples following standard methods. The maceral group composition, mean vitrinite reflectance in oil (R^o_m %) and microlithotype composition were studied and are exhibited in Tables 2 & 3.

RESULTS & DISCUSSIONS

The coal samples of Korba coal basin have colour varying from gray black – dull black to pitch black. Lithotype composition of Lower Barakar seams vary from fusanic – vitranic – claroduranic to vitrainic – claranic – duranic type. Lower Kusmunda Bottom (LKB) and equivalent of this seam (Jatraj group of seams) of Upper Barakar Formation indicate claranic – claroduranic – duranic type. Lower Kusmunda (LK) coal seams belonging to Upper Barakar Formation have claroduranic – clarainic – vitrainic type whereas Upper Kusmunda (UK) coal seam may be defined as clarainic – vitrainic type. The technological properties of coal samples viz. moisture (W^a), volatile matter (V^{daf}) and ash (A^d) are placed in the range of 6.22 – 12.40, 31.62 – 45.65 and 9.87 – 35.16(wt %) respectively (Table 2). The fuel ratio (FR) of the coal samples

vary from 1.19 – 2.16. The carbon content (C^{daf}), hydrogen content (H^{daf}), oxygen content (O^{daf}) and nitrogen content (N^{daf}) vary from 68.24 – 80.07, 5.24 – 6.62, 12.16 – 22.74 and 1.69 – 2.37(wt %) respectively. Sulphur content in coal samples are less than 1.00 wt %. The mean vitrinite reflectance in oil (R^o_m %) ranges from 0.41% – 0.50%. The relationship between H/C and O/C of all samples show high coefficient of determination ($r^2 = 0.85$) (Figure 2) (van Krevelen, 1951, 1952, 1961). This relationship indicates normal coalification course for these coals. The rank of Lower Barakar Formation coal seams ranges from high volatile bituminous to low volatile bituminous whereas the Upper Barakar Formation coal seams are placed in the range of sub-bituminous to high volatile bituminous coal (Teichmüller, 1987; Stach et al., 1982; Taylor et al., 1998). The vitrinite composition (Vt^{mmf}) in Lower Barakar Formation seams vary from 27.84 – 37.59 (vol. %) whereas in Upper Barakar Formation seams it ranges from 44.00 – 81.76 (vol. %). The vitrinite group is differentiated into telinite, collotelinite, vitrodetrinite, gelinite and corpogelinite. Inertinite content (I^{mmf}) in Lower Barakar Formation seams vary from 58.70 – 70.52 (vol. %). In the samples from Upper Barakar seam, inertinite content ranges from 17.40 to 55.71 (vol. %). The liptinite content (L^{mmf}) is small and varies from 0.84 – 3.71 (vol. %) (Table 3). Inertinite content appears to decrease in younger stratigraphic horizons and vitrinite content appears to increase from older seam (Lower Barakar Formation) to younger seam (Upper Barakar Formation) which may be due to the evolution of woody plants and their accumulation in forest swamps concomitant with increase in groundwater level. The Lower Barakar Formation coal have undergone through dehydration, desiccation and oxidation of organic material which led to the formation and predominance of inertinite macerals. In Upper Barakar Formation seams, the environmental condition changes to more anoxic reducing environment which led to formation of vitrinite macerals which is evident by increase in bright band thickness within seam. Figure 3 depicts the relationships between vitrinite and inertinite content of the samples while relationship between vitrinite and inertinite content is shown in Figure 4. Figure 3 indicates strong inverse relationship which supports their common phytogenic precursor for existence of two genetic tracts. The significant feature is the lower maximum percentage of inertinite in comparison to vitrinite (Figure 3). It indicates, under the condition of fusinitization more cell tissue is destroyed in comparison to vitrinitization (Littke, 1985). This results in enrichment in liptinite component and other resistant mineral matter (non-tissue component). Similarly the relationship between vitrinite and inertinite also supports the above observation (Figure 4). The relationship between tissue preservation index (TPI) and gelification index (GI) is exhibited in Figure 5. This figure points that tissue preservation takes place with gelification of organic material. The V/I ratio (vitrinite to inertinite) shows good correlation with GI (Figure 6). The relation between vitrinite and GI is exhibited in Figure 7 and shows very high coefficient of determination ($r^2 = 0.99$). It has been observed that when vitrinite content exceeds 65 vol. %, a slight increase in vitrinite causes exponential increase in gelification. The microlithotype composition was plotted in double triangle of Hacquebard et al. (1964, 1967) to decipher coal facies (Figure 8) (Marchioni, 1980; Diessel, 1992). The upper triangle suggests that organic (plant) materials have collected in a continuously wet forest swamp with consistently high groundwater table. Coal facies include lakes and ponds which collect detritus blown or washed in all other parts of the swamp. The lower triangle also supports the above observation. The coal facies of Korba coal basin appears to vary from telmatic – limno-telmatic – limnic (Figure 8). The carbominerite and rocks of coal samples vary from 32.84 to 68.77 vol. %. These amounts of carbominerites are likely to be separated as middlings whereas rocks may be separated as rejects or dirt during beneficiation (Table 3).

CONCLUSIONS

- The significant growth between coal and mineral matter in form of carbominerite was observed.
- The rank of coal ranges from sub-bituminous to low volatile bituminous.
- Coal facies vary from telmatic – limno-telmatic – limnic.

REFERENCES

1. CIL, 1993. Coal Atlas of India. Coal India Limited, 104 – 105.
2. CMPDI, 2013. Inventory of Coal Resources of India. 2013 report. www.cmpdi.co.in/coalinventory/php
3. Diessel C.F.K., 1992. Coal bearing depositional system 1991, 1961, 88 – 120.
4. GSI, 1983. Coalfields of India, Ed. C.S.Raja Rao, Bull. Geol. Surv. Ind. Series A, No 45, Pl. III, 21-34.
5. Hacquebard P.A., Alexander R., Cameron A.R., Donaldson J.R. 1964. Die Ablagerungsbedingungen des Flözes Habour im Sydeny-Kohlengbiet von Neuschottland (Kanada). Fortschr Geol. Rheinld Westf, 12, 331-356
6. Hacquebard P.A., Birmingham T.F., Donaldson J.R. 1967. Petrography of Canadian coals in relation to environment of deposition. Symp Science and technology of coal, Ottawa, Dep Energy, Mines and Resour, 84-97
7. ICCP, 1971. International Committee for Coal Petrography 1971, 2nd edition, CNRS, Paris.
8. ICCP, 1998. The new vitrinite classification (ICCP system 1994). Fuel 1998. 77, 349 – 358
9. ICCP, 2001. The new inertinite classification (ICCP system 1994). Fuel 2001. 80, 459 – 471
10. Littke R., 1985. Aufbau and Entstehung von Flözen der Dorstener, Horster und Esserner Schichten des Ruhrkarbons am Beispiel der Bohrung Wulfener Heide 1. Boch Geol Geotech Arb 18.
11. Marchioni D.L., 1980. Petrography and depositional environment of the Liddell Seam, Upper Hunter Valley, New South Wales. International Journal of Coal Geology, 1, 35 – 61.
12. Stach E., Mackowsky M.-TH., Teichmüller M., Taylor G.H., Chandra D., Teichmüller R., 1982 Stach's Textbook of Coal Petrology. Gebrüder Borntraeger · Berlin · Stuttgart.
13. Teichmüller M., 1987. Organic material and very low-grade metamorphism. -In: Frey, M.(Ed.): Low Temperature Metamorphism, Blackie, Glasgow, 114 – 161.
14. Taylor G.H., Teichmüller M., Davis A., Diessel C.F.K., Littke R., Robert P., 1998. Organic Petrology. Gebrüder Borntraeger · Berlin · Stuttgart.
15. Van Krevelen, D.W., 1951. The H/C versus O/C diagram. – C.R. Congr. Int. Strat. Géol. Carbonifère, 3ed session, Heerlen, 359.
16. Van Krevelen D.W., 1952. Some chemical aspects of coal genesis and coal structure. CR 3rd Int Congr Carbon Strat Geol, Heerlen 1951, 1, 195 – 212.
17. Van Krevelen D.W., 1961. Coal – typology, chemistry, physics, and constitution. Elsevier, Amsterdam.

APPENDICES

Table 1: Stratigraphic Succession of Korba Coal Basin (after CIL, 1993)

Age	Formation	Thickness(m)	Lithology
Recent	Alluvium	Up to 20	Soil & Sub-soil
Lower Triassic to Upper Permian	Kamthi	+ 200	Coarse ferruginous sandstone, pebbly sandstone, conglomerate and clay.
~~~~~Un-conformity~~~~~			
	Upper Barakar	+ 500	Sandstone, shale, carbonaceous shale and <b>thick coal seams</b> .

Lower Permian	Middle Barakar	+ 100	Sandstone of varied grain sizes, mostly pebbly sandstones and conglomerate.
	Lower Barakar	+ 375	Predominantly coarse grained to pebbly sandstone with <b>thin superior coal seams</b> .
-----Disconformity-----			
Lower Permian	Talchir	+ 250	Fined grained compact sandstone, tillite and greenish shales & conglomerate
~~~~~Non-conformity~~~~~			
Archaean	Metamorphics Granite, Gneisses, etc.		

Table 2: Location, Technological Properties, Carbon and Hydrogen Content of Coal Samples

CS	Fm	Se/Ln	W ^a wt %	V ^{daf} wt %	A ^d wt %	FR	C ^{daf}	H ^{daf}
M13	UB	Kusmunda	12.40	41.39	13.36	1.42	70.54	6.21
L12		Laxman	6.43	40.22	35.16	1.49	73.14	6.36
K11		Laxman	9.67	43.09	18.73	1.32	72.30	6.24
J10		Gevra	10.24	45.65	28.80	1.19	68.24	6.62
I9		Dipka	8.92	44.95	31.66	1.22	69.15	6.52
H8		Kusmunda	7.63	43.35	25.95	1.31	73.14	6.14
G7		Gevra	9.16	44.29	25.02	1.26	71.00	6.53
F6		Dipka	8.83	41.05	18.64	1.44	73.95	6.11
E5		Manikpur	8.18	42.10	24.58	1.38	73.09	5.96
D4		Kusmunda	6.22	43.02	34.27	1.32	72.95	6.52
C3		Balgi	8.03	32.13	13.97	2.11	78.35	5.27
B2	LB	Surakachar	6.76	31.62	13.59	2.16	80.07	5.24
A1		Banki	8.72	35.81	9.87	1.79	77.34	5.52

Explanations= CS: Coal Sample; Fm: Formation; Se/Ln: Seam/Location; LB: Lower Barakar; UB: Upper Barakar; W: Moisture Content; V: Volatile Matter Content; A: Ash Content; FR: Fuel Ratio; C: Carbon Content; H: Hydrogen Content; a: Analytical State; daf: Dry Ash Free Basis;

Table 3: Petrographic Characteristics of Coal Samples

CS	Maceral Group Composition (vol. %)				Microlithotype (vol. %)					R ^o m% (in Oil)
	V _t ^{mmf}	I ^{mmf}	L ^{mmf}	MM	Mom	Bim	Trm	Cam	Roc	
M13	70.40	27.50	1.13	14.10	42.97	20.09	0.00	24.46	12.47	0.47
L12	44.00	52.31	3.69	35.00	32.84	11.03	0.00	38.83	17.29	0.47
K11	76.29	22.68	1.03	25.04	44.11	11.76	0.45	29.98	13.69	0.42
J10	81.76	17.40	0.84	25.93	53.72	4.62	0.00	23.26	18.38	0.50
I9	56.66	40.92	2.42	28.79	29.25	5.15	0.00	41.14	24.44	0.41
H8	51.21	47.25	1.54	24.17	46.66	7.00	0.00	21.14	25.18	0.46
G7	79.79	17.11	3.09	21.01	50.71	11.36	0.12	24.40	13.40	0.48
F6	72.11	26.83	2.05	16.75	51.05	16.10	0.00	26.27	6.57	0.48
E5	44.96	52.72	2.33	26.29	45.20	13.75	0.00	29.07	11.96	0.47
D4	41.58	55.71	2.72	29.23	37.02	9.05	0.00	38.92	15.00	0.45
C3	34.65	62.41	2.95	17.40	45.11	14.17	0.13	33.03	7.54	0.46
B2	27.84	70.52	1.62	26.95	23.61	7.51	0.12	44.31	24.46	0.48
A1	37.59	58.70	3.71	21.64	54.09	11.18	0.00	25.36	9.36	0.47

Explanations= CS: Coal Sample; V_t: Vitritine; I: Inertinite; L: Liptinite; mmf: Mineral Matter Free Basis; MM: Mineral Matter; Mom: Monomacrerite; Bim: Bimacerite; Trm: Trimacerite; Cam: Carbominerite; Roc: Rocks; R^o m%: Mean Vitritine Reflectance

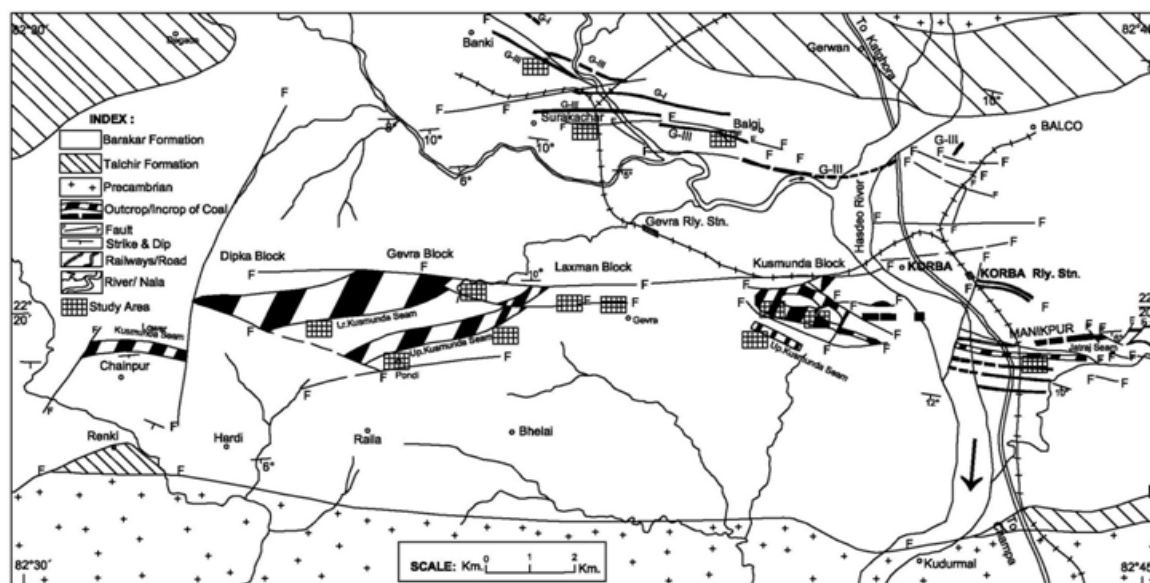


Figure 1: Geological Map of Korba Coal Basin, Chhattisgarh, India (after GSI, 1983)

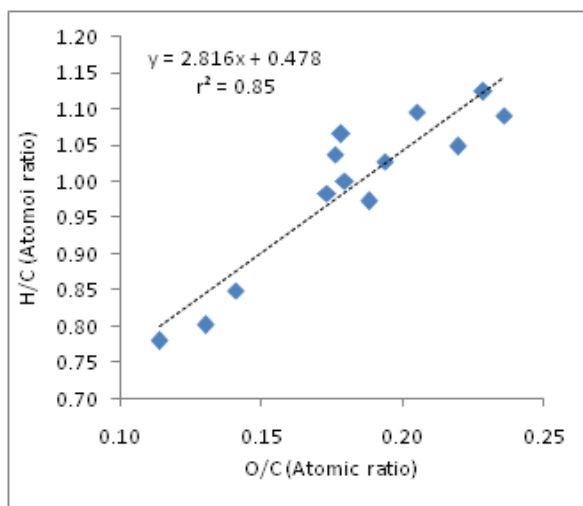


Figure 2: Relationship between H/C and O/C

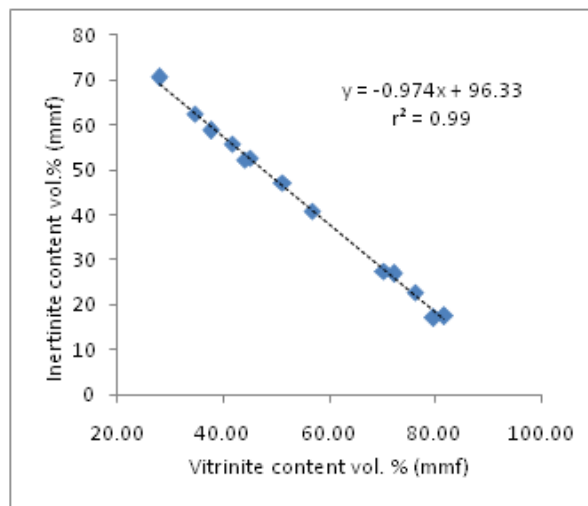


Figure 3: Relationship between Vitrinite and Inertinite

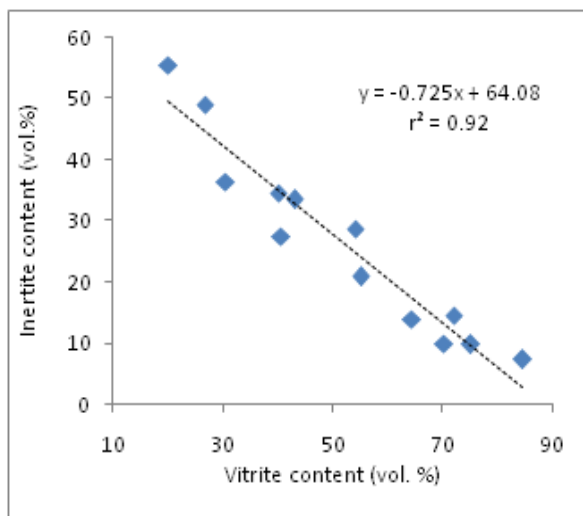


Figure 4: Relationship between Vitrite and Inertite

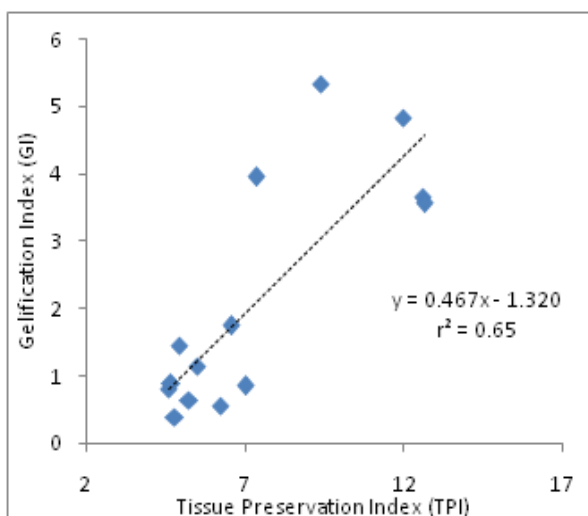


Figure 5: Relationship between TPI and GI

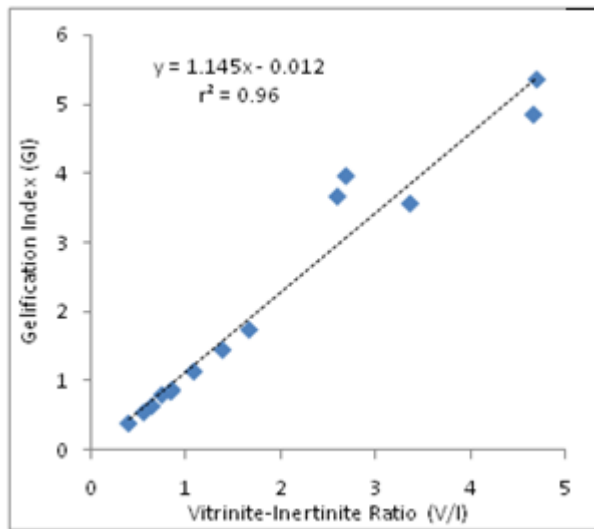


Figure 6: Relationship between V/I and GI

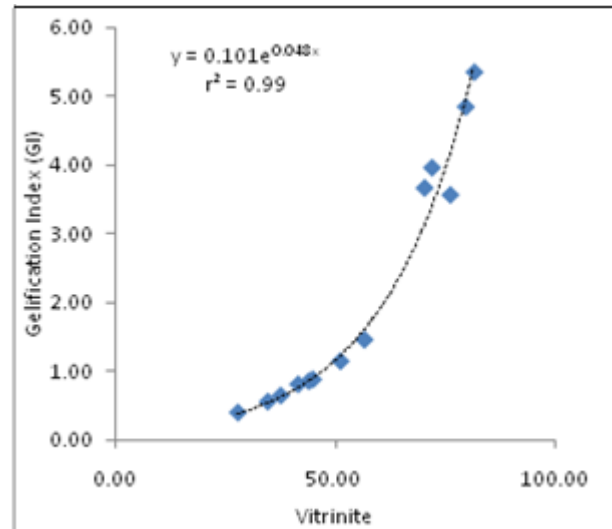
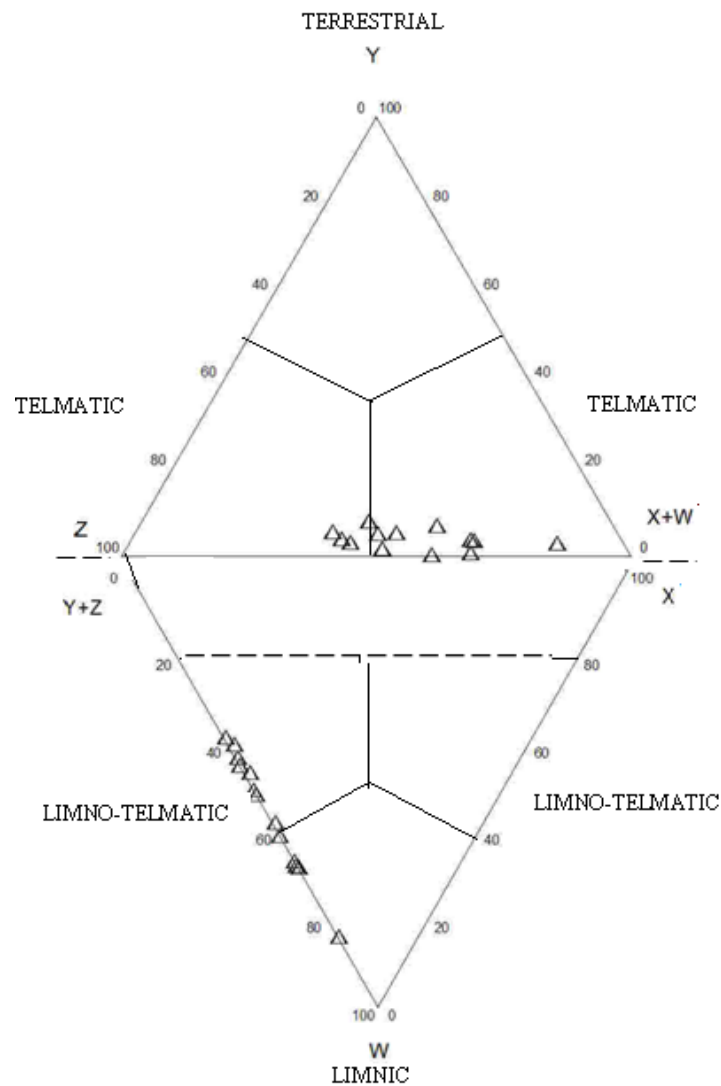


Figure 7: Relationship between Vitritine and GI



Explanations= X: Clarite-L + duroclarite + vitrinetoliptite; Y: duroclarite + vitrinertite-I; Z: clarite-V + vitrite + cuticlocclarite + vitrinertite-V; W: clarodurite + durite-I+durite-L + macroite + carbominerite

Figure 8: Double Diagram Indicating Microlithotype Composition and Coal Facies

